‘Are game mechanics mappable to learning taxonomies?’

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Can the game mechanics which promote learning be catalogued? To address this question, a framework is designed to investigate both the learning aspect whilst integrating the ludic dimension. In an effort to validate the hypotheses, Bloom’s revised taxonomy provides the learning criteria, whilst the game mechanics are provided through the filter of commercial games and gamification systems. Finally, for the purposes of testing, a playable prototype game example is designed and created specifically for the task, containing specific measurable learning objectives, and tested with students, aiming at recording how they perceive the connection between the game mechanics of the prototype and the provided learning elements.

Game design, game mechanics, learning, learning taxonomies, Blooms taxonomy, education, edutainment, serious games, serious gaming, gamification, playful interaction, e-learning, games for health

1. Introduction: The methodology of mapping game mechanics to learning taxonomies.
For the purposes of investigating game mechanisms that promote learning, our first hypotheses must be to question if specific game mechanisms are mappable to a recognized learning taxonomy, and if these game mechanisms are able to support and promote learning outcomes. For this purpose, due to its correspondence with various learning mechanisms investigated, Blooms revised taxonomy (Krathwohl & Anderson, 2001) is preferential as a framework due to its simple, easily understandable terminology, i.e. six easily recognisable definitions: remember, understand, apply, analyse, evaluate and create. Bloom’s taxonomy will be utilised as a learning framework against which the actual learning can be mapped through quantitative and qualitative research (playtesting, questionnaire, interviews). The gameplay mechanisms provided to the students for prototype creation and case study testing were adapted from the provided literary review, commercial game and gamification mechanisms, and the authors own personal experience within game development. Please note that the list was provided as a guide only – attempting to provide an exhaustive list of all game mechanics is beyond the scope of this study. A student prototype ‘Important events in the life of Harriet Tubman’ was utilised as the case study in the testing stage. The game development students who created the prototype were given freedom to utilise whichever game mechanics were ‘fit for purpose’ from the provided list, and also encouraged to utilise their own within the construction of the prototype. Specific utilised mechanics from the list are discussed within the case study and contained within Table 1. An expanded list was made available to all the participants during the testing. For a mechanism to be deemed effective, within a certain taxonomy, it must be mapped to that specific category by the majority of the test subjects within that particular analysis filter. For successful learning to have been confirmed within the context of the study, certain measurable learning objectives were built into the example prototype that must have been seen to be fulfilled. This is discussed within the example case study.

2. Literature review:

2.1 Game Design:
In respect of its aims, game design has many considerations that are unique among other types of software development (Pinelle, Wong & Stach, 2008). Other academics have sought to identify an overarching set of design principles, or principles aimed at specific elements such as engagement, but this study is not directed toward design principles as a whole, rather the mechanics ‘mappable’ against learning taxonomies. As Deterding argues, ‘current models of video game motivation do not connect to the granular level of single design elements’ (2011, p 1). This paper aims to provide game mechanics to be tested for such motivation in a learning framework, providing a proven and testable mechanic set from both commercial games and education. As an analytical method, the core pillars of game construction must be considered.

2.2 Game Design taxonomies: Basic gameplay loops

To analyse mechanisms in games, we must first understand the basic components. One of the primary functionalities recognized within games is the 'gameplay loop' (Florian, 2012), consisting of objective, challenge, and reward. These elements are discussed below.

2.3 Objectives

Early games such as 'Pong' (1972, Atari) had simple, clear objectives – get the ball past the opponent for a high score. Modern games, although frequently based around a single main objective frequently contain sub quests or side missions, primarily for the purposes of extending playtime or replayabilty. Ideally, game objectives are immediately clear to the player. Clear objectives can also aid learning; a case study of 'the multiplayer classroom' described how, after introducing RPG style quests into her class, a high school biology teacher found that having an objective and reward at the end of the class was 'great motivation for them to do more work' (Sheldon, 2011, p.55). Objectives in games are designed to motivate – are there mechanisms available that will succeed in the same motivation in the learning environment? An example of one such mechanism, used frequently within this field, is narrative. The difference between narrative in games and narrative in other forms of media being that the player has control over the character and, in many cases, the story. Aarseth (2003, p.5) states: 'Players do not regard their engagement with a new literary or cinematic work as a learning process, which every player of a new game must and does.' Jackson (2009, p8) cites narrative within games as aligning with Papert's Syntonic learning (1980), i.e. 'Learning that takes place because the learner identifies with the task, object, context, and/or character'. This agency creates powerful associations for the player, giving a sense of 'ownership [and allowing] a sense of self-control and self-determination' (Gee, 2005). Sheldon also argues that it gives players choices and a 'stake in the game' (2012, p.38).There are many thousands of motivators (as above) utilized within game systems, and drilling down to locate the most effective from a learning perspective is the focus of this study. So, with many ways to motivate, entice and drive the player through the game, which elements or systems represent 'play'?

2.4 Challenges

Csikszentmihalyi analysed the player's sense of 'flow' (1997, p.66), a state achievable through an optimal balance of challenge vs. ability. He describes the ideal requirements: 'Human beings feel best in flow, when they are fully involved in meeting a challenge, solving a problem, discovering something new. Most activities that produce flow also have clear goals, clear rules, and immediate feedback – a set of external demands that focuses our attention and makes demands on our skills' (p.66). Videogame designers have levered the concept of flow and elements such as clear goals and immediate feedback into modern game design for decades (Chen, 2007). Mirrored in the difficulty curve of games, the player is directed towards clear objectives as the challenges in the game increase (Lee & Hammer, 2011). Challenges in video games prevent the player from reaching the goal, or final objective directly. In a correctly balanced game, the player will make many mistakes to reach this objective. Van Eck (2006, p.5) describes the gameplay process as a 'constant cycle of hypothesis formulation, testing, and revision' – and in this scenario mistakes are an important part of the process. Sheldon (2011, p.XV) argues that 'the primary way that players learn is from making mistakes'. Making mistakes in games is indeed a powerful tool, allowing players to experiment with game systems and mechanisms without real world consequences. This raises questions of how to keep players motivated and learning from their mistakes. McGonigal (2011) describes the feeling of player agency as the key: 'the players hadn't failed passively. They had failed spectacularly, and entertainingly' (p. 76). In games such as 'Limbo' (Playdead, 2010) and 'Trials HD' (RedLynx, 2009), the fascinating ways in which the player is able to die are rewards in themselves. As Jackson, says players 'can take risks and learn from their mistakes because they can make multiple attempts' (2009 p.3). Rapid 'respawn' or rapid feedback cycles are vital in this process (Lee & Hammer, 2011). Being delivered back into the game world further re-enforces the lack of consequences. In education, on the other hand, 'the stakes of failure are high and the feedback cycles long' (Lee & Hammer, 2011 p.4). In circumstances where the player is overwhelmed by the challenge, this means no more than re-starting the level or choosing a different route or strategy with which to approach the problem; however, in education, overwhelming the learner with information could be potentially catastrophic. As Jenovah Chen, designer of the influential 'Journey' states: 'simply increasing the number of choices is costly […] when people can't decide what to choose, they are at a loss' (2007, p.33). In the case of mechanisms promoting learning in games, it would seem 'reduced options' are important, certainly in the early or training stages. This directly mirrors a Gamification technique described as 'onboarding' (Zichermann & Cunningham, 2011), where the player is given only limited choices and positive re-enforcement within the first moments of a game; as Zichermann & Cunningham describe 'train and engage, but don't overwhelm' (2011, p.59). Onboarding also finds parallels in Yusoff, Crowder, Gilbert and Wills's 2009 study into a framework for serious games; one of

the aspects of a game which supports 'learning and engagement' is 'scaffolding', or 'the support and help given by the game during the learning activities' (Yusoff, Crowder, Gilbert & Wills, 2009, p.22). This also a component of Blooms 'mastery learning', where a student or player achieves a certain skill or cognitive level before the next become accessible or, as Smith puts it, 'to reach the next level of learning, the learner must first master the level before it' (1981, p.7). Jackson (2009, p.4) argues that to keep players within their 'zone of proximal development' (Vygotsky 1978, p 86), or maximum learning zone, a certain level of mastery must be reached before they are allowed to progress. In game terminology this is called 'gating' (Hauteville, 2011), where a player should only be allowed access to a new area when they have mastered the pre-requisite set of skills. Robin Walker, one of the game designers of 'Portal' (2007), discusses this concept in an early introduction to the in game portal mechanic: 'Completing the puzzle requires walking through a minimum of five portals in a specific order. This kind of gating, in which a solid understanding of key gameplay concepts is required for success, helped standardize the learning curve of the game tremendously' (The portal wiki, 2010). Blooms 'cognitive domain' taxonomy (Bloom, Engelhart, Furst, Hill & Krathwohl, 1956) features this 'scaffolding' structure that maps so clearly against 'gating' and the onboarding mechanisms so prevalent within onboarding. This early area of the game, within the context of the onboarding, is frequently referred to as the 'sandbox' area. Not to be confused with the game genre where the player is allowed free agency within the world, sandbox in this instance refers to a safe environment where the player can safely learn new game mechanisms or strategies without threat of death, time limits, or enemies. Aarseth, (2003) describes the learning within a game as a progression of exploring and experimenting with techniques; the sandbox area, where the player is usually required to learn the basics of the game system, is designed for this purpose. Indeed, the sandbox environment seems to mirror basic human learning needs. Bjorklund and Pellegrini argue in their chapter 'Homo Ludens', that 'human children have so much to learn that they require not only a long time to learn it, but also safe environments in which to master their eventual adult roles' (2002, p.331), or, as Gee describes them, sandboxes allow 'exciting play where, in this case, things can't go wrong at all' (2005, p.21).

Learning also requires reflection on what has been learnt, which Yusoff, Crowder, Gilbert & Wills describe from the learner point of view as assessing 'the purpose of the learning activities that have been undertaken, and deciding the strategy to apply during the next activity' (2009, p.23). The sandbox area allows for failure without consequences. Koster argues that 'fun is about learning in a context where there is no pressure, and that is why games matter' (2005, p.99), or as Chatfield argues in his TED talk on game behaviourism, '[give the player things they can] manipulate and play with and where the feedback comes, then they can learn a lesson, they can see, they can move on, they can understand' (Dotsub, 2010).

2.5 Rewards

The next component in the gameplay loop of objective/challenge/reward, rewards are arrangements in the game to encourage the learner and to keep their motivation high. (Yusoff, Crowder, Gilbert & Wills, 2009 p.22). Rewards in commercial games are as varied as auditory and visual feedback, points, levelling and 'powerups'. Feedback is something that games are designed to provide. With the proliferation of motion control devices, games are more than able to deliver the visual, auditory, and kinaesthetic learning style variations familiar to educators. Players receive rapid frequent feedback guiding them to a goal: it is crucial to the player understanding that they are on the correct route. This is referred to by developers as 'signposting' or 'breadcrumbing' (Bacher, 2008, p.14). One of the primary concerns for the designer is that this feedback is happening 'rapidly and frequently' (Van Eck, 2006, p.5) and as Chatfield puts it 'virtuality is dazzling at delivering this' (Dotsub.com, 2010). This rapid feedback is also vital in Learning. Fink argues that feedback should be immediate, and close to the learning activity itself, i.e. 'With delayed feedback […] students cease to care about why their answer or activity was good or not' (2003, p.128). In Gamification, points are utilized as an important reward system. Deterding (2010) argues that rewarding points for the simplest action, the player clicking at regular intervals to receive rewards is valueless. This was satirised by Ian Bogost's cow-clicker (Facebook, 2012), which highlighted the meaningless nature of virtual rewards: Robertson named this 'pointsification' (2010). It mirrors Skinners' 1940 behaviourism experiments; indeed returning each day to tend your crops in Farmville (Zynga, 2009) and its Gamification definition as 'appointment gaming' (Gamasutra, 2010) only serve to re-enforce this view. These same points systems are described as 'feedback loops' (Zichermann, Cunningham, 2011; Kim, 2000); the sense of scores and levels as providing 'clear and unambiguous feedback to the player that she is heading in the "right" direction' (Zichermann & Cunningham 2011, p. 77). But can points ever be recognized as a reward in themselves, other than collecting enough for a 'free coffee at Foursquare' (Lashke, 2011, p.3)? Yes, perhaps in the case of education, they can. Points have

different meaning and value within an educational context. Points or grades are markers with which to measure learning. In a real world context, points must be treated carefully; indeed, evidence indicates that children who are good at a particular activity will lose interest once rewards, trophies, or competition are introduced and/or removed, a concept known as 'over-justification' (Zichermann, 2011b). Other successful reward systems should be noted; 'achievements', popularized by the Microsoft XBOX and now an 'integral part of Xbox 360 gaming' (Jakobsson, 2011), involve rewards being afforded to the player for completing particular in game quests, or in many cases unique challenges set by the game designers, i.e. 'Perform an air assassination on a poisoned NPC' from 'Assassin's Creed 2' (Ubisoft, 2009). Badges, the gamification version of achievements also allow the player 'bragging rights' (Deterding, 2010), or an opportunity to show off their accomplishments (Zichermann, 2011) or, in cases such as 'GetGlue' (GetGlue, 2010), personalize their television viewing preferences and discover like-minded companions. Deterding (2010), argues that bragging rights are a predominantly male interest, and target audiences must be investigated carefully. Is there a place in the classroom for a version of bragging rights? Certainly, if handled correctly, elements such as avatar improvements (i.e. new outfits and personalization for your player character) serve both ownership and promote engagement with the game, and perhaps learning environment.

3. Example case study and testing:

3.1 Research methodology

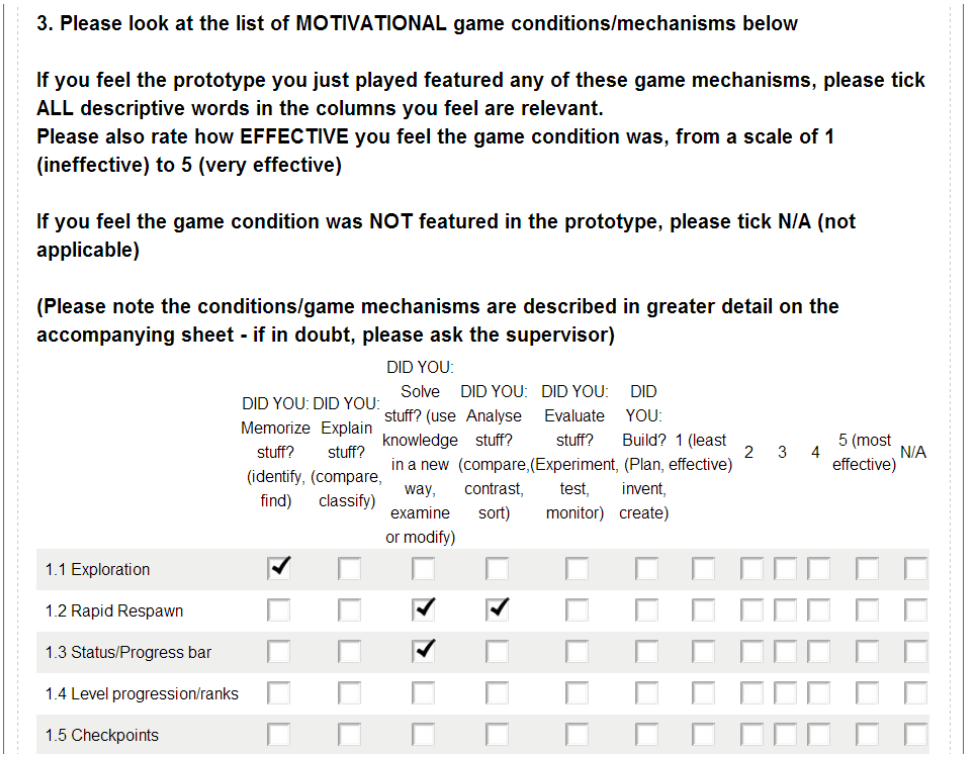
As discussed Bloom's taxonomy is utilized as a form of classification (Butler, Markulis & Strang, 1985, p.86), the goal of the research being directed specifically toward correlating Bloom classification against game mechanics.

3.2 Quantitative/qualitative data

The questionnaire was organized with the aims collecting the largest amount of information in the most efficient way for analysis. In that respect, a quantitative digital survey was organized, while qualitative data and feedback was observed and collected on the test days.

3.3 Test specifications

The Bloom's taxonomies' conditions were displayed against mechanics, as per the example below (fig. 1). The component sets were the students were allowed multiple inputs in each bracket of Blooms taxonomy.



3. Please look at the list of MOTIVATIONAL game conditions/mechanisms below

If you feel the prototype you just played featured any of these game mechanisms, please tick ALL descriptive words in the columns you feel are relevant.
Please also rate how EFFECTIVE you feel the game condition was, from a scale of 1 (ineffective) to 5 (very effective)

If you feel the game condition was NOT featured in the prototype, please tick N/A (not applicable)

(Please note the conditions/game mechanisms are described in greater detail on the accompanying sheet - if in doubt, please ask the supervisor)

	DID YOU: Memorize stuff? (identify, find)	DID YOU: Explain stuff? (compare, classify)	DID YOU: Solve stuff? (use knowledge in a new way, examine or modify)	DID YOU: Analyse stuff? (compare, contrast, sort)	DID YOU: Evaluate stuff? (Experiment, test, monitor)	DID YOU: Build? (Plan, invent, create)	1 (least effective)	2	3	4	5 (most effective)	N/A
1.1 Exploration	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
1.2 Rapid Respawn	☐	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐	☐
1.3 Status/Progress bar	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐
1.4 Level progression/ranks	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
1.5 Checkpoints	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 1. An example of the online case study questionnaire format

Mechanic type	Name	Description
Teaching	*Safe environment (Safety first!)*	*Players should always be given the tools and taught the initial steps of any gameplay mechanic or system in a safe environment!*
Teaching	*Readability/consistent rules*	*Once you've taught the player a visual language, you MUST adhere to that visual language (E.g. the colour coded environment of Mirrors Edge))*
Teaching	*Embed/embedded*	*Important knowledge or information can be embedded in cutscenes, audio logs, or environment. (E.g. Bioshock, Left4dead intro movie)*
Objectives and Motivators	*Multiple quests*	*Give the player other routes when tired of the main quest*
Objectives and Motivators	*Storyline*	*The story of the game is motivating the player to keep playing and exploring the world*
Objectives and Motivators	*Signposting /breadcrumbing*	*Lead the player via lights, medi-packs etc.*
Challenge	*Free access (Roaming)*	*Allowing the player access to areas with challenges outside of the regular difficulty curve – allowing for bonuses – or death!*
Challenge	*Pattern recognition/memory*	*Learning certain game patterns or systems that result in modifiers or other rewards.*
Win/Lose	*Subterfuge*	*The player has to accomplish a certain objective without being detected or revealed*

Table 1: Abridged/Example list of primary case study game mechanisms (as provided to students)

3.4 Test subjects/location

The testing took place within the faculty for International Game Architecture and Design, part of NHTV University of Applied Sciences campus, Breda, Netherlands, using first year students enrolled on the game design fundamentals course, from the programming and Independent game development streams. The students were all computer literate and well versed in the ethos of gaming. This information was validated by strict initial tests for entrants to each of the streams. The majority of the students comprised of English speaking Dutch or German students, with a minor representation from the UK, Poland, and Russia. The game design fundamentals' course taught to the students involved was designed to describe the basic component sets, and mechanism subsets, that make up commercial games. These were investigated across a variety of provided game genres in the classroom environment, and a card set provided describing these mechanisms was created and made available (Fig.2). This process was used as an introduction to the full mechanic set (examples within Table 1). This game component and mechanic focussed card set was informed and inspired by 'The deck of lenses' (Schell, 2008) card set based around the popular 'The Art of Game Design: A Book of Lenses' (Schell, 2008).

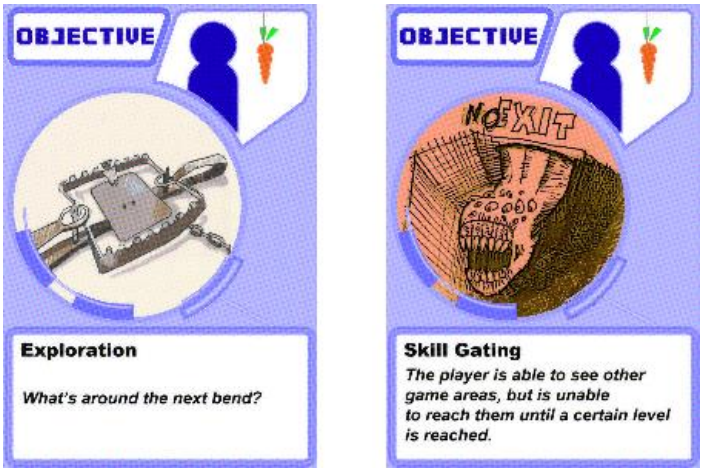


Figure 2. Example Game Mechanic cards

4. Example Case study – 'Important events in the life of Harriet Tubman':

4.1 Overview

'Important events in the life of Harriet Tubman' is a first person view prototype game developed in the Unity engine, based around Harriet Tubman, an influential female figure within the slave abolitionist movement during the American civil war. This game was based in a large open world environment based around the geographical locale of Maryland. Nine participants took place in the case study.

4.2 Learning objectives

In the context of Bloom's taxonomy, the creators specified two learning measurable learning goals based around 'remembering' and 'understanding' in the revised taxonomy – more specifically that the player remember and understand information regarding Harriet Tubman and her role within the abolition of the slave movement. This information was delivered via the loading screen, and within the descriptions provided by the quest givers. If the quests were accepted in order, and hence all of the historical information built into the game provided in order, for the purposes of the study, the learning objective within the context of the game was recognised as fulfilled.

4.3 Game objectives and Primary featured Mechanisms

A description of the case specific game mechanisms within the context of the case study follows. These are presented as per the order of introduction within the game and shown in italics. The same mechanics are also specified within Table 1. The Primary game objective was to find the underground railway, and escape the area, as introduced via a notice board beside the player start position (fig. 3) other information, such as a map of Maryland was *embedded* within the loading screen, outlining the events and objectives in a historical context;

Figure 3. The noticeboard at the start of the game.

Figure 4. The first *quest giver*.

Game objectives were delivered by a number *quest givers (*fig 4), who also introduce a *storyline* element, as well the initial *exploration* objective of finding the next *quest giver* within the woods surrounding the player. The player has no specific boundaries, and is allowed *free access/roaming* across the majority of the map, other than areas where they are corralled or blocked by raised ground at the edges of the playable area. This *safe environment* promotes exploration, the only real challenge in the game being slaver camps (fig.5), which, if approached, display an on-screen warning to move out of view. The player is guided, or *signposted* in the correct direction by gas lamps (fig.6), and upon reaching the second quest giver, is directed toward a side mission, *collecting* pages of a diary scattered through the woods. The second quest giver also warns about following the road, promoting the *subterfuge* mechanic. Finally, *pattern recognition* is noted – learning the placement of the enemy camps is an important aspect of progressing.

Figure 5. Enemy camp notification.

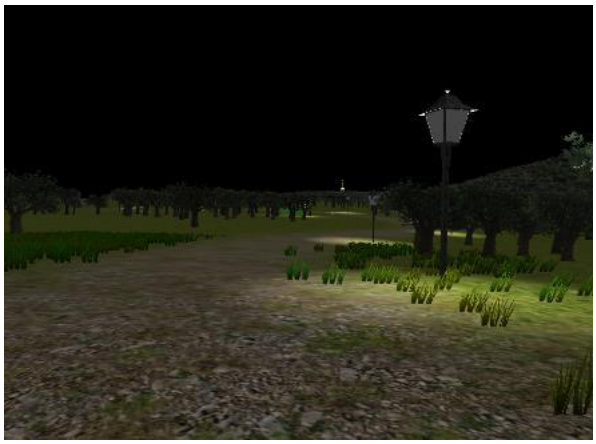


Figure 6. *Signposting*

5 Results – 'Important events in the life of Harriet Tubman':

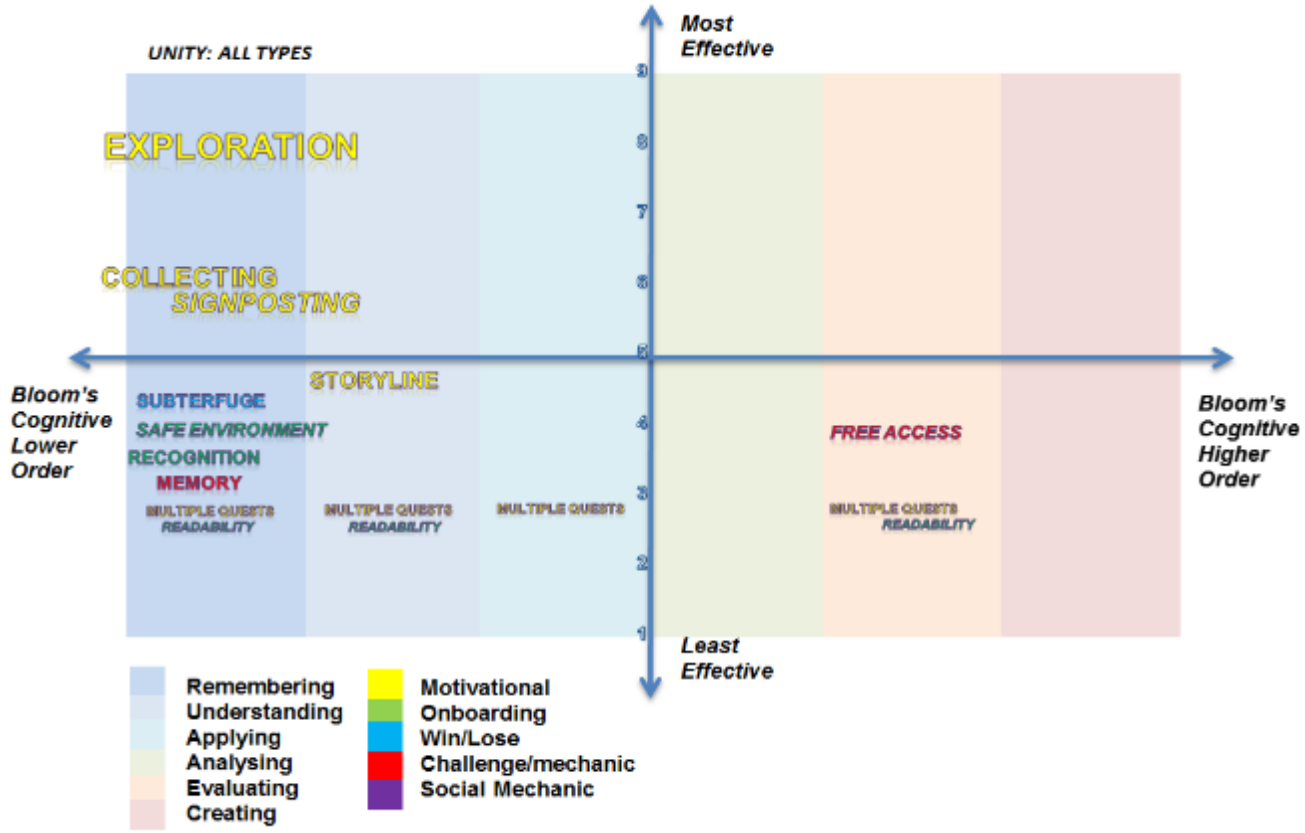


Figure 7. Results for All player types.

As described in (fig. 7) *Exploration* was found to be the most prominent mechanic, with eight out of the nine participants mapping it against the remembering category of Blooms. In the context of the information provided by the quest givers i.e. 'go to point A, B, etc.' *exploration* seems closely tied to the remembering aspect of Bloom's taxonomy. It is noted that a number of participants headed for the visible spire of a distant church. On arrival, a quest giver informs them 'there is nothing here, please go away!' (Bloemhoff, 2013). Or as a player noted; 'Exploration is not rewarded, even though it is encouraged by points in the distance (the church)' (fig.8).

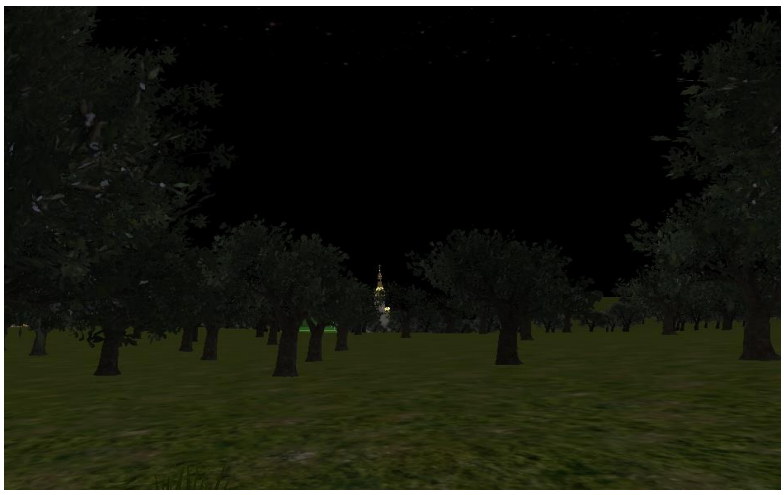


Figure 8. The distant church

This comment suggests that exploration is expected to be rewarded in some way – even if the reward, in the case of the other *quest givers* is simply information guiding them to the next objective. In the context of a learning situation it would seem that information itself can be seen as a reward as long as it is guiding the player toward an objective. Within the higher leaning objective of evaluation, *Free Access/roaming* rated relatively highly. Once provided with quests, players would probe the environment testing various routes out to see which one was most effective or garnered the most rewards. *Collecting* again introduced by the *quest givers*, clearly maps alongside *exploration* within the remembering category of Blooms. Even If this sub-quest is not investigated by the player, is this also perceived as a reward? Could this type of sub-quest be used to 'sugar coat' learning information? *Signposting* and *subterfuge* as information received from the quest givers i.e. 'stay on the road' and 'avoid slaver camps' are also mapped into the remembering category. This would seem to link directly to the necessity of remembering the route or map layout. One explorer player notes; 'Trying to not get detected when reaching a goal is a quite powerful win/lose condition'. *Storyline* was also relatively highly placed within the understanding category, although actual story featured minimally within quest objectives. It seems *storyline* is keenly sought by game players.

6 Conclusion

This example case study investigated the possibility, via the frameworks of player types and learning taxonomies, a system of measuring the 'success' of game mechanisms that guide the player to learning. Although mechanisms can clearly be mapped to learning taxonomies, other variables apparent within the case studies must be taken into consideration. Game genre is a vital factor in how a mechanism is perceived. For instance, *exploration* within an open world game that seeks to simulate elements of the real world is perceived entirely differently in a stylised 2D platformer that focuses on interaction between objects. The learning goals in this study were assumed to be achieved to by completion of a wide range of player tasks such as 'completing the level'; this suits for a umbrella categorization of all mechanisms within that completed level as promoting learning, but for a more precise study of the efficiency of particular learning outcomes granularity must be addressed; It would be suggested that real, measurable, testable learning content must be built into the game if future work is to be conducted in this area. In addition, the inclusion of some form of player type taxonomy is suggested with regards stereotypical behaviours and how they motivate the player type; i.e., do explorers or gatherers aim to find new and unique areas and then share their new knowledge, or as Bartle (1996, p.4) puts it 'making the most complete set of maps in existence'? Do killers head straight for the

objective without taxing themselves with the digression of exploration? Although further research is clearly needed in this area, if a definitive taxonomy of testing was constructed which aimed to recognize the game mechanisms that promoted learning, this may form an important part of developing didactical structures to promote learning of knowledge and skills across all ages and learning groups.

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